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POTENTIAL OF THERMAL ENERGY ACCUMULATION IN DISTRIC HEATING SYSTEMS NETWORKS

The dependency of power causing heat energy accumulation in the networks on the ambient air temperature was analyzed. Accumulation potential of heating and non-heating seasons was determined. It was demonstrated that in ambient air temperatures below the minimum design temperature the heat accumulation in networks is impossible.

K e y w o r d s: heating networks, accumulation, heat load, temperature chart, heating power, heat carrier consumption, heat carrier temperature, potential.

Formulation of the problem. In using of electrothermal consumers-controllers (ETCC) in distric heating (DH) systems for frequency control and active power it is important to know what their power in the heating and non-heating periods can be and the how this power depends on the ambient air temperature. Currently these issues is studied insufficiently that can hamper ETCC implementation in DH systems.

Accumulation in heat supply network was studied in a number of works [1-3], covering the operation modes of heat consuming equipment during accumulation of heat energy in the networks, as well as limiting technical and institutional factors and issues on improving the reliability of thermal networks. These studies did not considered the dependency of power, causing the thermal energy accumulation in the networks, on the ambient air temperature.

The objective of the work is to determine the potential of thermal energy accumulation in the networks and its dependency on temperature.

Heat capacity accumulation is basically in heating systems. First a heat source heats the carrier (in fact the process of heat energy accumulation in the carrier takes place), then the carrier transfer the accumulated heat to consumers. Hereinafter the process of heat accumulation in the heat supply networks means the increasing of number of networks heat by excessing the temperatures and/or heat carrier consumption, regulated with temperature chart.

The power supplied to the networks is distributed as follows: one part of it comes to loss compensation, the other – to cover the heat load of consumers, and the third one causes accumulation of heat energy circulating in the networks.

The intensity of heat losses depends on many factors: carrier temperature, condition of insulation, pipe laying method, weather conditions, groundwater level, etc. In the first approximation, the heat losses can be taken as a percentage of power at the input of heat networks. Taking into account the above mentioned the balance of powers for the heating network with or without accumulation can be written as

$$P_{м} = P_{н} + \delta P_{м} + P_a, \qquad (1)$$

$$P_t = P_{н} + \delta P_t\,, \qquad (2)$$

where $P_{м}$, P_t – power, which is supplied to the heating network, in accordance with and without accumulation;

$P_{н}$ – power covering the heat load;

P_a – power causing the accumulation in the heat networks;

δ – relative heat losses in the networks.

Based on (1) and (2) we can show that

$$P_a = (P_м - P_t)(1 - \delta). \quad (3)$$

Neglecting minor changes in specific heat and density depending on the temperature [4], we can express $P_м$, P_t through the heat carrier consumption, temperature difference, specific heat capacity and density of the heat carrier. Then the formula (3) will take the form

$$P_a = KC\rho(G_2\,\Delta T_A - G_1\,\Delta T_t)(1 - \delta), \quad (4)$$

where G_1, G_2 – heat carrier consumption in the steady mode (according to the temperature chart) and with accumulation, respectively;

ΔT_t, ΔT_A – difference of carrier temperature between the supply and return pipeline in steady mode and with accumulation, respectively;

K – correction factor, which takes into account accumulation capacity of materials in the heating networks.

Take G_2 in the form

$$G_2 = G_1 + \Delta G, \quad (5)$$

where ΔG – increment in heat carrier consumption.

Substituting (5) to (4) and making the necessary changes we get

$$P_a = KC\rho[G_1(\Delta T_A - \Delta T_t) + \Delta G \Delta T_A](1 - \delta). \quad (6)$$

It can be shown that

$$\Delta T_A - \Delta T_t = \Delta T1 - \Delta T2 \quad (7)$$

where $\Delta T1$, $\Delta T2$ – increments of carrier temperature in supply and return pipelines.

Substituting (7) to (6) we get

$$P_a = KC\rho[G_1(\Delta T1 - \Delta T2) + \Delta G \Delta T_A](1 - \delta). \quad (8)$$

As the expressions (6) and (8) show the accumulation of heat energy in the networks is possible only by increasing the temperature of the carrier and/or increasing its consumption.

Consider the process of heat energy accumulation during heating and non-heating seasons. During the heating season the DH systems use quality control (heat carrier consumption is constant, temperature changes in the supply pipeline). Then the expression (6) takes the form

$$P_a = KC\rho G_1(\Delta T_A - \Delta T_t)(1 - \delta) \quad (9)$$

The maximum possible power at heating network input (potential) can be determined based on the expression (9)

$$P_{am} = KC\rho G_н(\Delta T_{max} - \Delta T_t)(1 - \delta), \quad (10)$$

where P_{am} – the maximum power that can cause the heat accumulation in the network (the maximum power of ETCC at discharge of heat energy into the network);

$G_н$ – regulatory heat carrier consumption;

$\Delta T_{max} = T1_{max} - T2_{max} = 80°C$ maximum difference of carrier temperature between the supply and return pipelines for temperature chart 150/70°C;

$T1_{max}$, $T2_{max}$ – maximum temperature in the supply and return pipelines.

Function $\Delta T_t = f(t°)$ is piecewise linear, thus the function $\Delta T_{max} - \Delta T_t$ will also be piecewise linear. This function can be present analytically using the system of equation below, and its graph is shown in Figure 1.

$$\Delta T_A = \begin{cases} 52{,}5, & t \geq 4°C \\ 2.0192t + 44{,}4224, & 4°C \geq t \geq -22°C \end{cases} \quad (11)$$

The graph shows that at the design temperature –22°C the function value $(\Delta T_{max} - \Delta T_t)$ is zero. Thus, the expression (10) at this point is zero. This means that at ambient air temperature $t° \leq -22°C$ the accumulation in the heat networks is impossible. This is explained by the fact that the parameters of the heat carrier reached the maximum permissible values for the safe operation of the network, and all energy compensate the heat load and losses. Then, at increasing the ambient air temperature the accumulation potential increases and reaches the maximum value at the culminating point of temperature graph +4°C.

For example, according to the formula (10), the accumulation potential of heat energy in main piping networks of six sources in Kharkiv regional heat supply system is defined, a summary of which is presented in the Table 1.

Output data.

Temperature chart 150/70°C at the minimum design temperature minus 23°C; K=1.09 (taken for the average diameter of pipelines $D_у$= 400 mm); C = 4.178 kJ/kg°C; ρ =958,05 kg/m^3; δ=0,07 (loss in main pipeline networks – 7%). The calculation results are shown as graphs in Figure 2. The pattern of the potential accumulation from temperature for

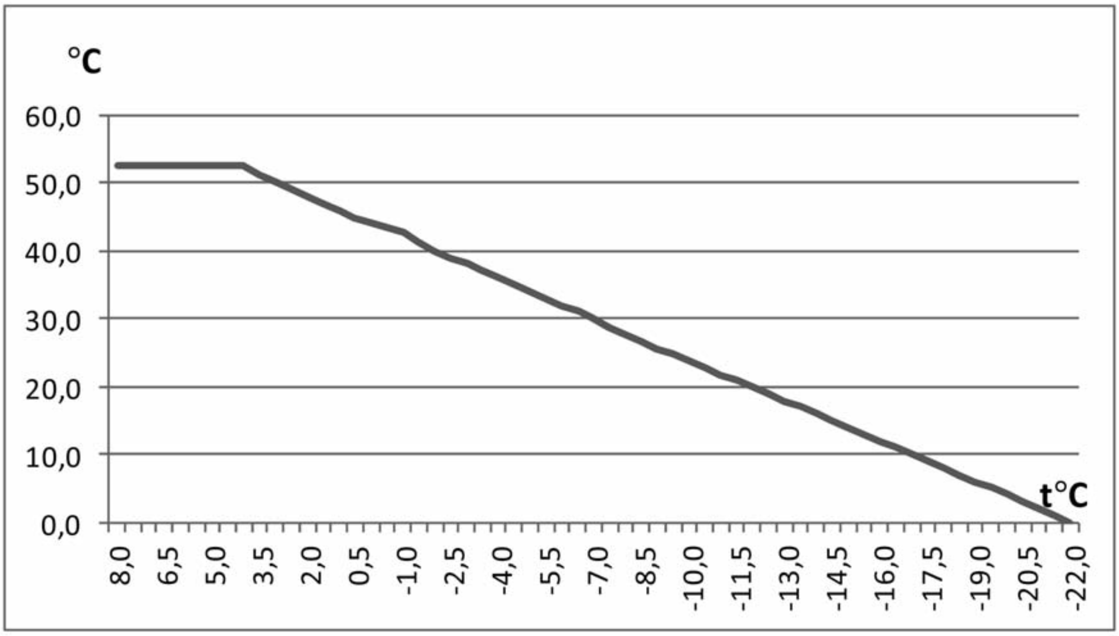

Figure 1. Function graph $(\Delta T_{max} - \Delta T_t)$

Table 1 **— Heating sources**

Heat energy source	Thermal load,		Standard heat carrier consumption ($G_н$)
	Gcal/h	MW	m^3/h
CHP – 5	944	1085.6	11800
CHP – 3	880	1012	11000
CHP – 4	620	713	7750
Boiler house No. 5	780	897	9750
Boiler house No. 6	340	391	4250
Boiler house No. 4	269	309.35	3363

all sources is similar to function ΔT_A, which is describe above.

During non-heating period the only load of DH system is hot water supply, which operates according the temperature chart 70/42°C. Heat carrier consumption is 2–3 times smaller than during heating season. Accumulation time of heat energy in the networks coincides with time of minimum hot water distribution. In order to be within the maximum heat carrier temperature in the return pipeline (70°C), heat energy accumulation must be done by increasing the heat carrier consumption at constant temperature in the supply pipeline. Based on (6) the expression for the maximum power, which causes accumulation, takes the form

$$P_a = KC\rho[\Delta G \, \Delta T_A](1 - \delta), \qquad (12)$$

where $\Delta T_A = \Delta T_t = 28$°C.

The accumulation potential during non-heating season was calculated for six heat sources of Kharkiv heat supply system. It was assumed that at the beginning of the accumulation the heat carrier

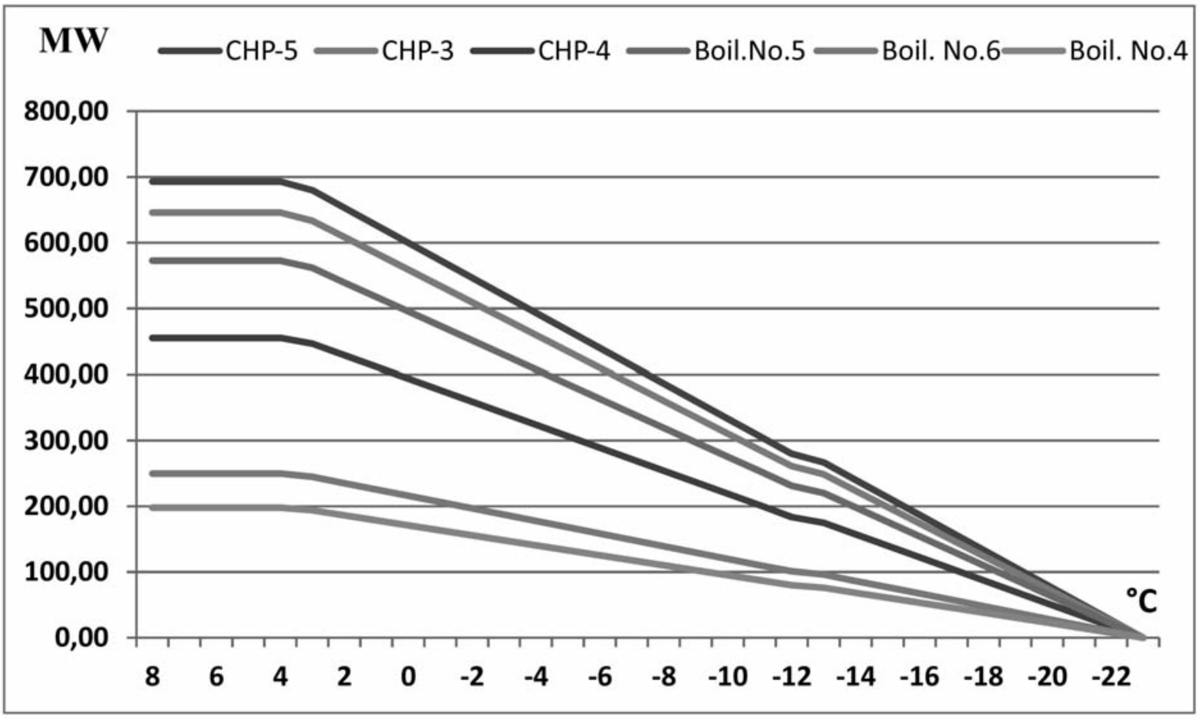

Figure 2. Dependency of accumulation potential on ambient air temperature

Table 2 **— Accumulation potential during non-heating season**

Source	Load of hot water supply, MW		Heat carrier consumption,	Accumulation potential,
	Maximum	Medium	m^3 /h	MW
CHP-3	297.32	76.33	4375.70	133.55
CHP-4	172.65	44.33	2540.86	77.55
CHP-5	353.44	90.74	5201.54	158.75
Boiler house No. 5	400.77	102.89	5898.16	180.01
Boiler house No. 6	94.55	24.28	1391.53	42.47
Boiler house No. 4	112.57	28.90	1656.65	50.56
Total	**1431.29**	**367.47**		**642.89**

flow was doubled. The calculation results are shown in Table 2.

In actual use the accumulation potential can be increased by 20-25% at the expanse of increasing temperature in the supply pipe up to 84-87 °C (provided that the extreme temperatures will not be increased in the return pipeline). Such capacity increment designed to compensate heat losses in the networks.

CONCLUSIONS

As a result the analytical expressions were obtained that allow to define the accumulation potential of heat energy in the networks and its dependency on the ambient air temperature.

1. It was found that the accumulation potential is proportional to ambient air temperature.
2. It was shown that at air temperatures lower than the minimum calculated one, heat accumulation in the networks is impossible and ETCC can operate only by replacing the energy of boiler house heat generators.
3. During non-heating season the thermal energy accumulation are limited due to the low heat load.

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